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RESEARCH ARTICLE

Species richness, geographical affinities and activity patterns of mammals in premontane Andean forests of the Magdalena River basin of Colombia

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Abstract

More than half of the population of Colombia is settled in the Magdalena River basin, resulting in high deforestation rates due to productive activities and urbanisation. Within this scenario of forest loss and ecosystem degradation, it is imperative to record and monitor the biodiversity in order to decrease and mitigate the negative consequences of human activities on species and ecosystems. For six years, we assessed the mammal species richness, abundance and activity patterns in premontane forests of the Magdalena River basin in the Department of Caldas, Colombia. We also presented additional information on the geographical affinities of this fauna. We recorded 101 species, seven of them endemic to Colombia, with Chiroptera being the richest order, followed by Rodentia. Most of the species are common and not listed in threatened categories and only four are vulnerable and two endangered, according to the Red List of the IUCN and the Ministerio de Medio Ambiente y Desarrollo Sostenible of Colombia. The mammalian fauna of the study area is similar to that of other lowland localities in the Neotropics and different to the fauna in highland localities, including the nearby ones. Specifically, this fauna was most similar to that in lowland Tolima and the Caribbean Region of Colombia, Venezuela and Costa Rica; however, when we accounted only for bat fauna, it was more similar to the fauna in Caribbean and Pacific Regions of Colombia. To secure the long-term persistence of these species, we recommend maintenance of the current corridors, such as riparian forests and living fences and an increase in the forested area.

Keywords

biodiversity, biogeography, Caldas, checklist, inventory, monitoring

Introduction

The Magdalena River basin is located in northern South America in Colombia (Morrone 2014). This river has its origin in the Andes mountains (Colombian Massif) and flows northwards between the Central and Eastern Cordilleras throughout the Magdalena River Valley, emptying finally into the Caribbean Sea (Hermelin 2016). Biogeographically, this basin is classified as the Magdalena Province and belongs to the Pacific domain, sharing a taxa composition with nearby Provinces, such as Guajira, Chocó-Darién and Cauca (Hernández-Camacho et al. 1992; Kattan et al. 2004; Morrone 2014).

This Basin is of great economic relevance for the country because a large part of the Colombian population and their productive activities are settled there (IDEAM 2001). Such a level of economic development has produced a continuous pressure on natural resources, resulting in high rates of deforestation mainly at low to mid elevations (Armenteras et al. 2013). It is estimated that around 70% of Andean and 30% of lowland forests in Colombia have been lost (Etter et al. 2006a, b), especially in the Magdalena River basin (Etter and van Wyngaarden 2000). The current landscapes in this basin are very heterogeneous, where forests are represented mainly by fragments immersed in an agricultural matrix with different levels of connection through riparian forests and living fences (Etter et al. 2008). The remaining extensive areas of forests are mainly associated with the Andean highlands, natural parks and private civil reserves, as well as hydroelectric dams (Armenteras et al. 2003).

In this context of forest loss and fragmentation, it is important to monitor the biodiversity in order to prevent, mitigate, compensate or correct the negative effects of socio-economic activities on ecosystems (Schmeller et al. 2017). An important tool for this purpose is species inventories which result in checklists, natural history field data and spatiotemporal trends in species richness and abundance (Christoffersen 2010, Lees et al. 2014). The data obtained from the previous activities allow the construction and improvement of species distributional hypotheses (Elith et al. 2006) and to the identification of evidence-based important areas for conservation (Niemelä 2000).

In the Magdalena River and its tributaries, mammal inventories can be tracked back as far as the 19^{th} century (Mantilla-Meluk et al. 2014) and, during the last decades, checklists have been frequently published (e.g. Moreno-Bejarano and Álvarez-León 2003; Castaño and Corrales 2010; Garcés Retrepo et al. 2016; Solari et al. 2020). However, most published inventories and monitoring are based on one year or less sampling efforts and the local mammalian richness is generally underestimated. Here, we provide a checklist for mammals from premontane forests on the eastern slopes of the Central Cordillera in the Department of Caldas, Colombia, as a result of field data collection distributed over six years (2014–2019). We also provide some insights into the geographical affinities of this fauna and data on their activity patterns.

Methods

Study area

The forests, included in this study, are distributed on the eastern slopes of the Central Cordillera in the Department of Caldas, Colombia. We surveyed forests in the Municipalities of Victoria, Norcasia and Samaná in an elevation range between 300 and 1000 metres. This heterogeneous landscape is composed of crops, pastures and natural vegetation, ranging from stubble to riparian forests and mature secondary forests. All sampling sites were located in the basin of the rivers Manso, Miel and Guarinó. These last two are tributaries of the Magdalena River. Sampling sites were under the influence of the area around the Miel I hydroelectric dam. The average temperature was 23 °C with a maximum of 33 °C with warmer conditions at lower elevations. Annual average precipitation varies from year to year between 3000 to 5000 mm and distributed in an annual bimodal pattern with December to February and June to August as the dry periods (IDEAM 2001).

Mammal sampling

We accumulated 647 sampling days during the six years (2014–2019). The samplings were distributed during both rainy and dry seasons. To capture bats, we used mist-nets installed in the understorey, across streams and at forest edges. Mist-nets remained open after sunset until 22:00 h. Manual captures were opportunistic, mainly associated with species roosting under small bridges, in hollow trunks or in the foliage. For mist-nets, a total of 34000 metres of net-nights was accumulated. For small and medium non-volant mammals sampling, we used live capture traps (Sherman and Tomahawk), located on the ground and up to two metres above the ground on branches. Traps were baited with a mixture of banana and oat, flavoured with vanilla essence or sardine and corn with bacon butter. Each trap was checked daily in the morning and the bait replaced with fresh bait. The traps were installed in linear transects by stations 10–15 m apart, for a total of 20–25 stations according to the available area at each sampling site. Each station contained a trap on the ground and a trap in the branches. In total, we accumulated 33455 trap-nights. Mammals were also sampled using trap-cameras (Bushnell) located along trials and streams where the passage of mammals was highly probable. Cameras were set 300 m apart at a minimum and we accumulated a total of 3435 hours-cam. Direct observations were also included.

Mammalian taxonomy and conservation status

For bat taxonomy, we followed Simmons and Cirranello (2020). For taxonomic updates in *Chiroderma* and *Tonatia*, we followed Lim et al. (2020) and Basantes et al. (2020). We treated *Glossophaga soricina* on the western side of the Andes as a differ-

ent species (here *Glossophaga* sp.), as suggested by Hoffmann et al (2019). We also treated the *Sturnira* in the study area as an undetermined species because some authors classify it as *S. parvidens* or *S. giannae* (García-Herrera et al. 2019; Esquivel et al. 2020); however, the distributions of these species are expected to be restricted to Central America and the Amazon basin, respectively (Velazco and Patterson 2019; Hernández-Canchola and León-Paniagua 2020). Thus, the populations in our study area cannot yet be confidently assigned to any species.

The taxonomy of non-volant mammals followed the Mammal Taxonomy Database of the American Society of Mammalogists (Burgin et al. 2018). For squirrels, we followed the taxonomic arrangement proposed in Fiedler et al. (2020) and for *Marmosa*, we followed Voss et al. (2020). Some specimens were collected, prepared as skull and skin and deposited in the Museo de Historia Natural of the Universidad de Caldas. All procedures followed the guidelines of the American Society of Mammalogists for the use of wild mammals in research (Sikes and Gannon 2011). The global status of conservation and population trends followed the Red List of the IUCN (www.iucnredlist.org). The national conservation status followed the Resolución 1912 of 2017 of the Ministerio de Ambiente y Desarrollo Sostenible.

Data analysis

To establish geographical similarities of the mammalian fauna in the study area with other areas of the Neotropics, we constructed a matrix of presence/absence of 548 species of mammals from data available from checklists for localities in Central America and northern South America (Suppl. material 1). We excluded the genera *Mazama* and *Sylvilagus* because it was not clear to what species to assign the species reported in the references. We gathered data for the following areas: (1) the Central Cordillera of Colombia on the western slopes in Risaralda (Castaño et al. 2018), Valle del Cauca (Rojas-Díaz et al. 2012), Cauca (Ramírez-Chaves and Pérez 2010) and the eastern slopes in Tolima (García-Herera et al. 2019); (2) the Western Cordillera of Colombia on both slopes at the Departments of Valle del Cauca and Cauca and the Pacific lowlands (Ramírez-Chaves and Pérez 2010; Rojas-Díaz et al. 2012); (3) the eastern slopes of the Colombian Massif in Cauca (Ramírez-Chaves and Pérez 2010); (4) the Caribbean Region of Colombia in Córdoba (Racero-Casarrubia et al. 2015); (5) the Orinoquía of Colombia in Arauca (Mosquera-Guerra et al. 2019); (6) the Guiana Shield in Colombia (Trujillo et al. 2018) and (7) French Guiana (Lim 2012); (8) the Amazonas in Venezuela (Lim 2012); (9) the Sierra de Aroa in Yarucay State in northern Venezuela (García et al. 2016); (10) Central America in Costa Rica (Rodríguez-Herrera et al. 2014); and (11) La Rioja in Argentina (Fariñas-Torres et al. 2018), this last locality being chosen to be used as outgroup.

For the Colombian Cordilleras, we grouped separately the mammalian fauna below 1000 m from that recorded over 2000 m of elevation to analyse them as different localities because highland mammalian fauna in the Andes tend to be different

from that in the lowlands (Mena et al. 2011; Velazco and Patterson 2013). Localities were clustered, based on the Jaccard Similarity Index using the algorithm Paired Group (UPGMA) in the software PAST (Hammer et al. 2001).

We assessed inventory completeness as RO/RE*100, where RO was the observed species richness and RE was the species richness estimated by the index Chao 1, calculated with the software ESTIMATES, based on a matrix of presence or absence of species and randomised 100 times (Colwell and Elsensohn 2014) using days as sampling units. Finally, as we did not intend to assess habitat use, but only activity patterns, we used raw total abundances obtained in camera traps, constructing a frequency distribution graph for each of the 24 hours of the day for species with 20 or more records. We presented a checklist for the area, including two additional species (*Mustela frenata* and *Centronycteris centralis*) recorded for the area by Castaño and Corrales (2007 and 2010), but not recorded in this study.

Results

Mammal richness

We gathered 9848 records of mammals (recaptures not included) representing 101 species from nine orders and 26 families (Table 1; Figs 1–4). Chiroptera was the richest order with 53 species, followed by Rodentia with 19 species. Two species are listed globally as Endangered and one as Vulnerable and four species are listed nationally as Vulnerable. Seven species are endemic to Colombia, most of them rodents (four species). The completeness of the inventory was 91.5% (Fig. 5).

Geographical affinities

The mammal fauna in the study area was most similar to the fauna on the eastern slopes of the Central Cordillera in Tolima below 1000 m (Fig. 6A). Concurrently, the fauna of these two areas was similar to the one of the Caribbean Region in Córdoba. Together, the fauna of these three areas grouped with that of the Sierra de Aroa in Venezuela and Costa Rica and formed a group with the fauna of the Venezuelan Amazon and Guiana Shield in Colombia and French Guiana. Altogether, this group was similar to another group containing the fauna of Central and Western cordilleras of Colombia (Fig. 6A).

When only bat richness was considered, the pattern of similarity amongst localities changes (Fig. 6B). Bat fauna in the study area was also more similar to the fauna of Tolima below 1000 m and both fauna were similar to those of the Caribbean in Córdoba. However, instead of grouping with Central America or the Sierra de Aroa, the bat fauna of these three areas was more similar to that in the Pacific area of Valle del Cauca and Cauca (Colombia). All fauna making up this group were similar to other groups formed by the bat fauna of Venezuelan Amazon and Guiana Shield (Fig. 6B).

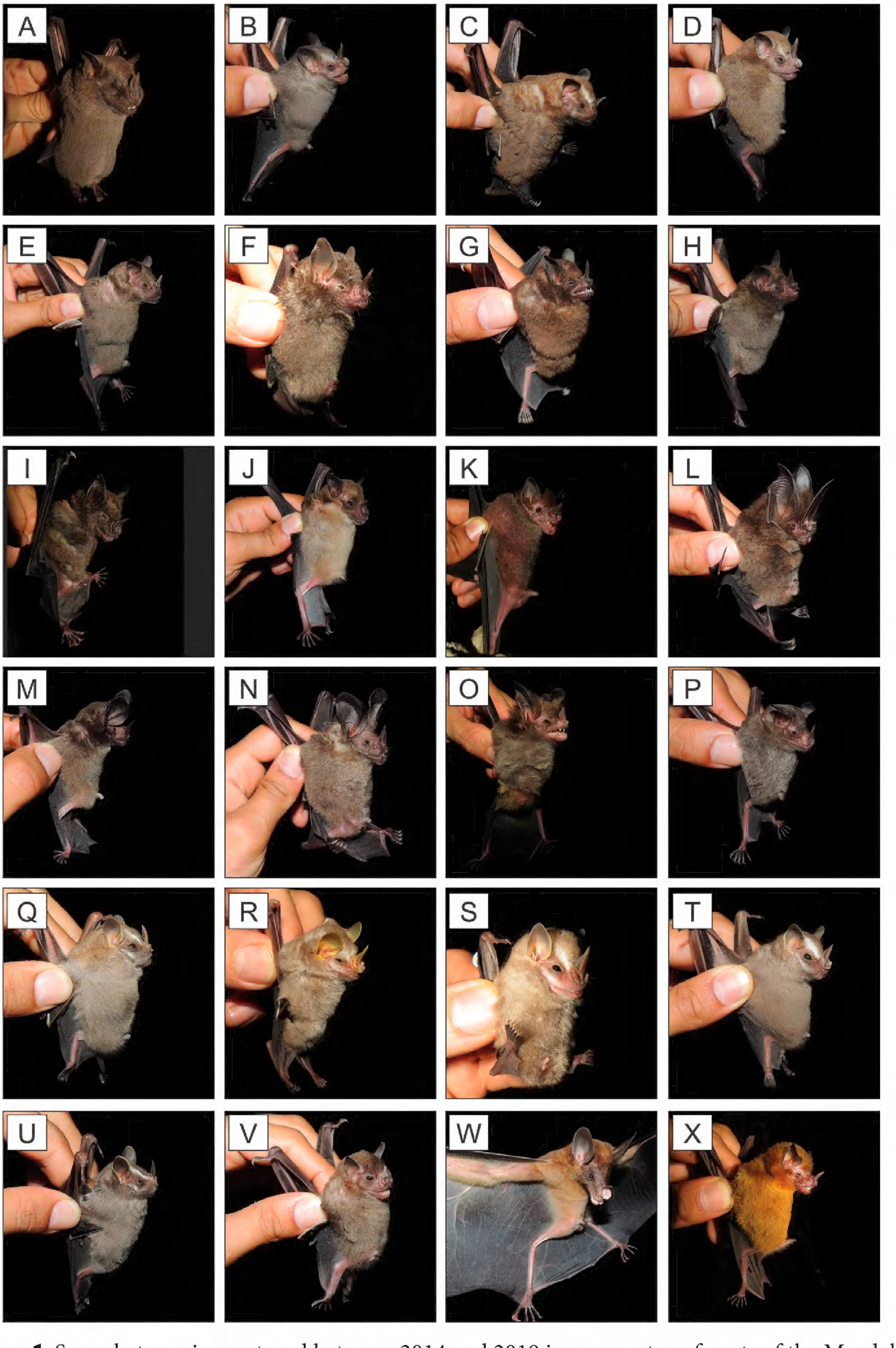

Figure 1. Some bat species captured between 2014 and 2019 in premontane forests of the Magdalena River basin in eastern Caldas, Colombia. *Artibeus amplus* (**A**), *A. phaeotis* (**B**), *A. lituratus* (**C**), *A. ravus* (**D**), *A. planirostris* (**E**), *Carollia brevicauda* (**F**), *C. castanea* (**G**), *C. perspicillata* (**H**), *Phyllostomaus hastatus* (**I**), *P. discolor* (**J**), *Phylloderma stenops* (**K**), *Lonchorhina aurita* (**L**), *Lophostoma brasiliense* (**M**), *L. silvicolum* (**N**), *Tonatia bakeri* (**O**), *Trinycteris nicefori* (**P**), *Chiroderma gorgasi* (**Q**), *Mesophylla macconnelli* (**R**), *Vampyressa thyone* (**S**), *Platyrrhinus helleri* (**T**), *Uroderma convexum* (**U**), *Sturnira* sp. (**V**), *Vampyrum spectrum* (**W**) and *Lampronycteris brachyotis* (**X**).

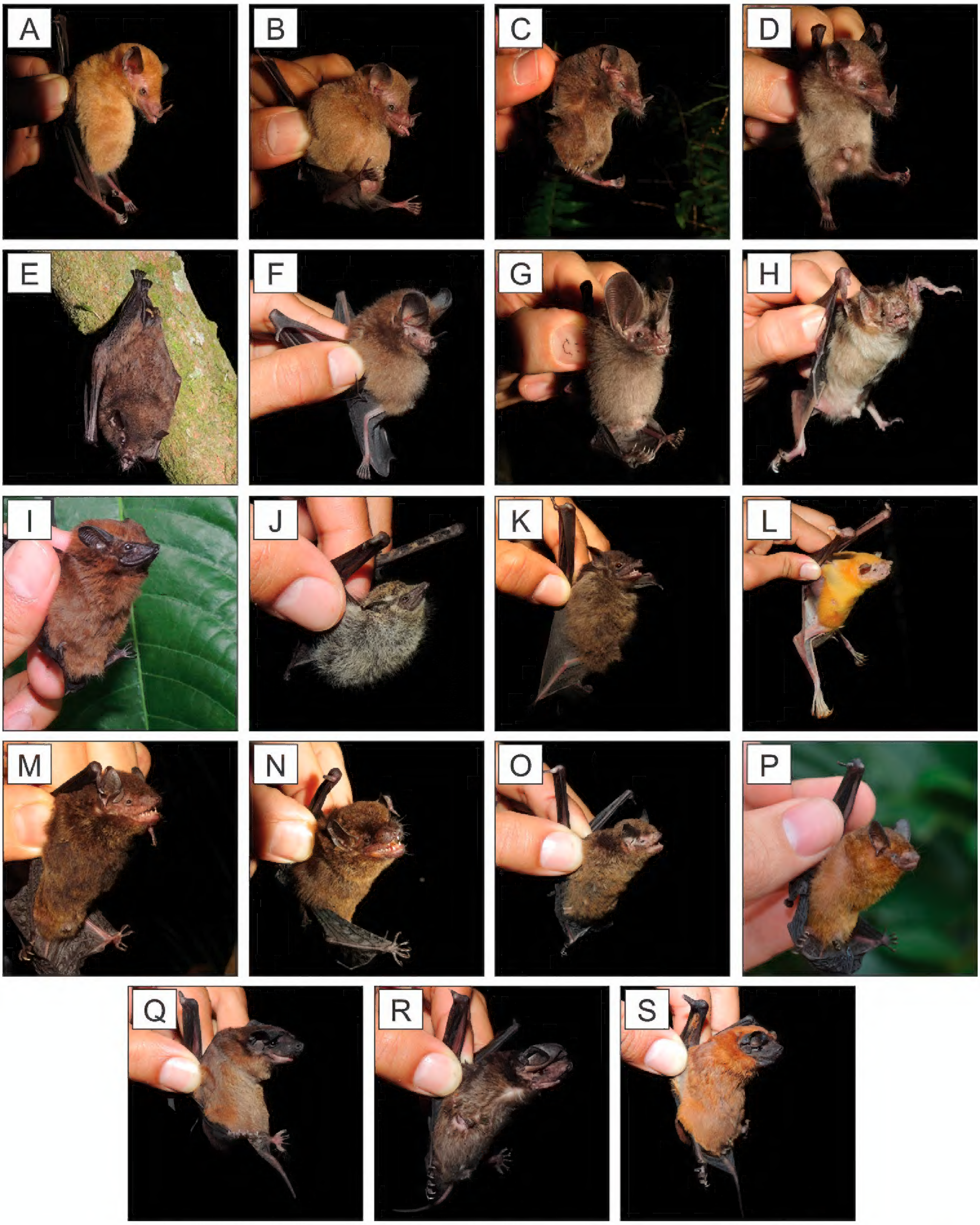

Figure 2. Some bat species captured between 2014 and 2019 in premontane forests of the Magdalena River basin in eastern Caldas, Colombia. *Lonchophylla robusta* (**A**), *Glossophaga* sp. (**B**), *Anoura caudifer* (**C**), *A. geoffroyi* (**D**), *Lichonycteris* aff. *obscura* (**E**), *Micronycteris microtis* (**F**), *M. schmidtorum* (**G**), *Desmodus rotundus* (**H**), *Cormura brevirostris* (**I**), *Rhynchonycteris naso* (**J**), *Saccopteryx bilineata* (**K**), *Noctilio leporinus* (**L**), *Eptesicus chiriquinus* (**M**), *E. brasiliensis* (**N**), *Myotis riparius* (**O**), *Rhogeessa io* (**P**), *Cynomops greenhalli* (**Q**), *Eumops hansae* (**R**) and *Molossus bondae* (**S**).

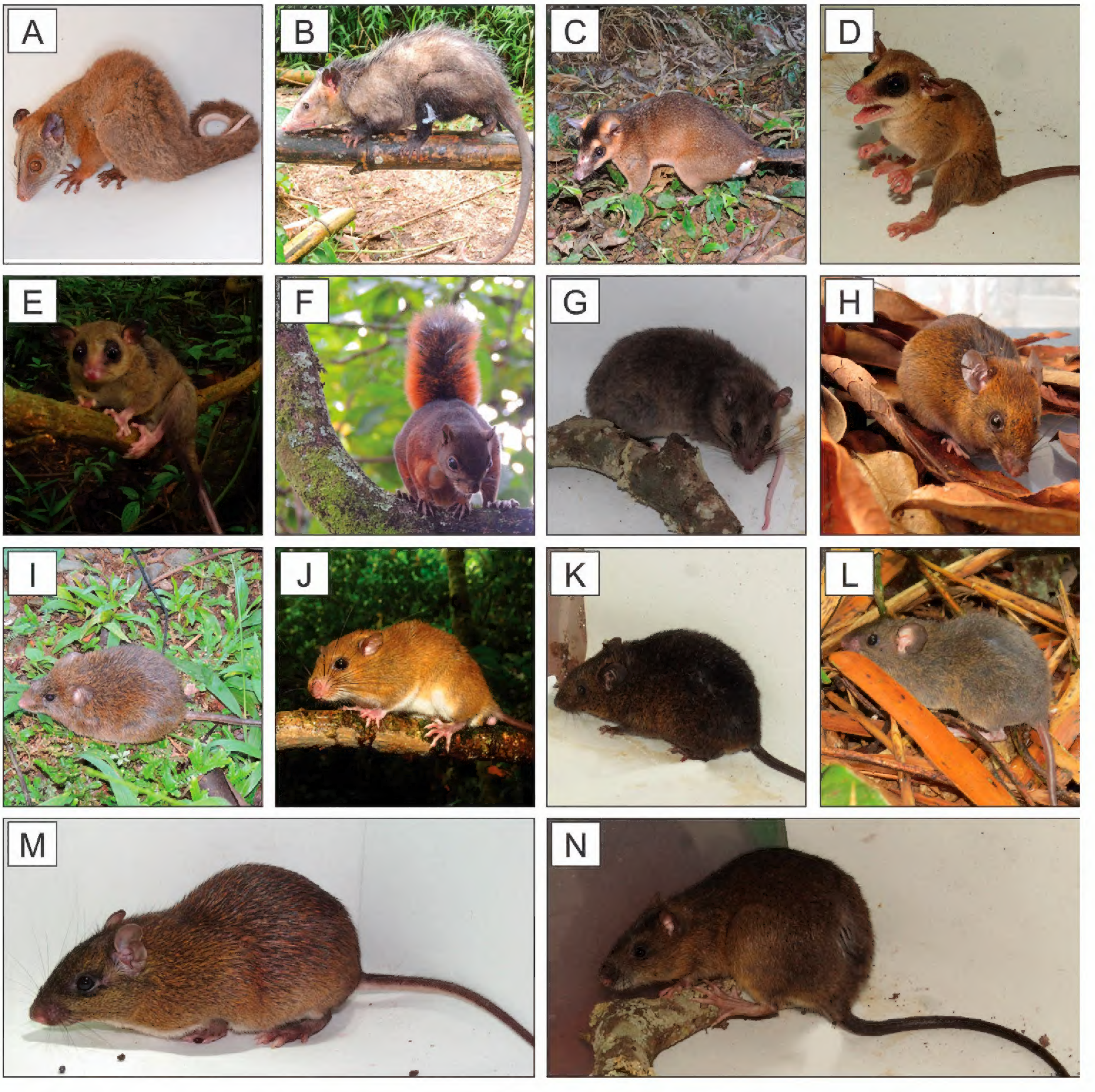

Figure 3. Some marsupials and rodents captured between 2014 and 2019 in premontane forests of the Magdalena River basin in eastern Caldas, Colombia. *Caluromys lanatus* (**A**), *Didelphis marsupialis* (**B**), *Metachirus myosuros* (**C**), *Marmosa isthmica* (**D**), *M. phaea* (**E**), *Syntheosciurus granatensis* (**F**), *Tylomys mirae* (**G**), *Transandinomys talamancae* (**H**), *Zygodontomys* aff. *brunneus* (**I**), *Rhipidomys caucensis* (**J**), *Melanomys caliginosus* (**K**), *Handleyomys alfaroi* (**L**), *Proechimys chrysaeolus* (**M**) and *Nectomys grandis* (**N**).

Activity patterns

Mammals showed three types of activity pattern (Fig. 7): (1) diurnal, including species as *Dasyprocta punctata* and *Eira barbara*; (2) cathemeral (active both at day and night), such as *Procyon cancrivorus*; and (3) nocturnal, like the rest of the analysed species. However, some species showed activities that fell out of their regular activity pattern; for example, *E. barbara* showed activity in the first hours after dawn and *Tamandua mexicana* and *Proechimys chrysaeolus* showed activity during the morning and noon. All the 10 analysed species showed some crepuscular activity.

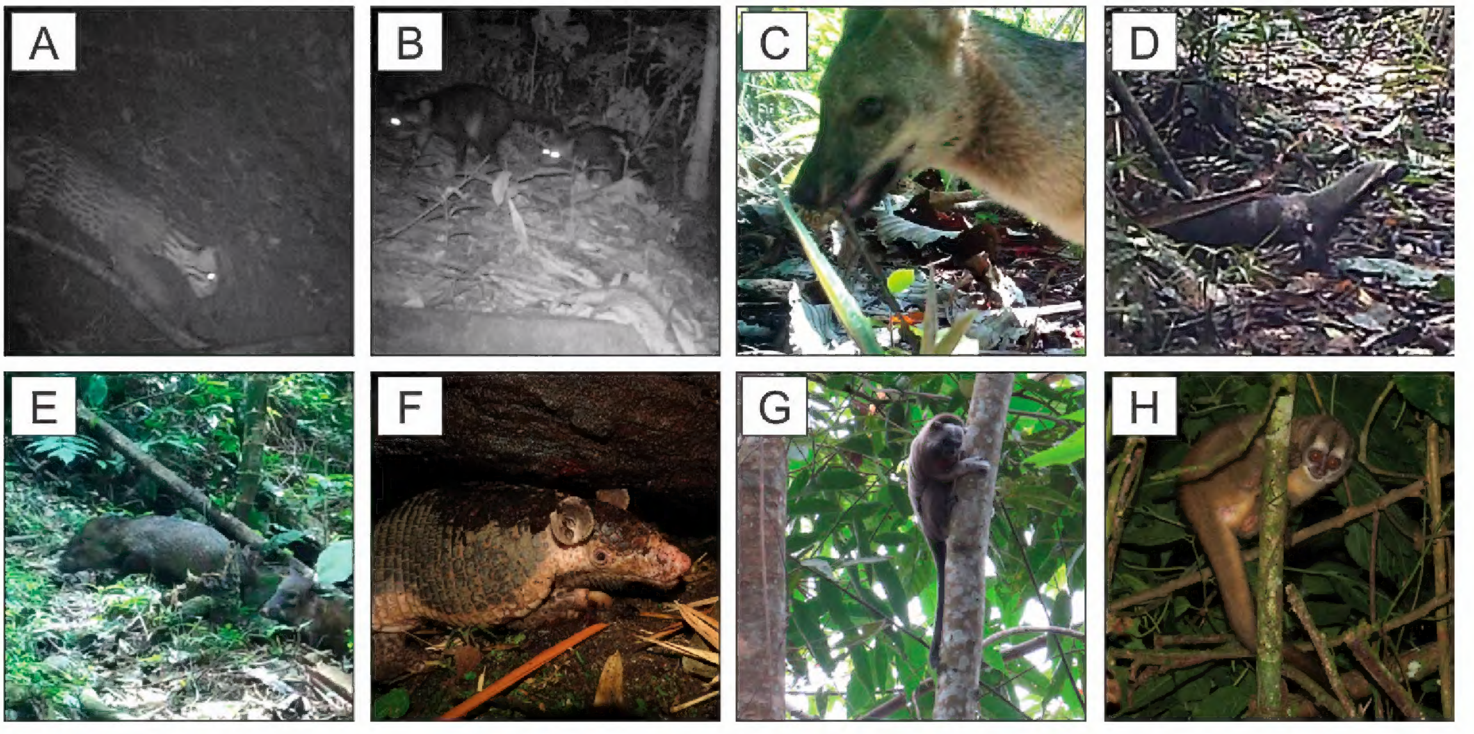

Figure 4. Some mammals registered between 2014 and 2019 in premontane forests of the Magdalena River basin in eastern Caldas, Colombia. *Leopardus pardalis* (**A**), *Procyon cancrivorus* (**B**), *Cerdocyon thous* (**C**), *Galictis vittata* (**D**), *Pecari tajacu* (**E**), *Cabassous centralis* (**F**), *Saguinus leucopus* (**G**) and *Aotus griseimembra* (**H**).

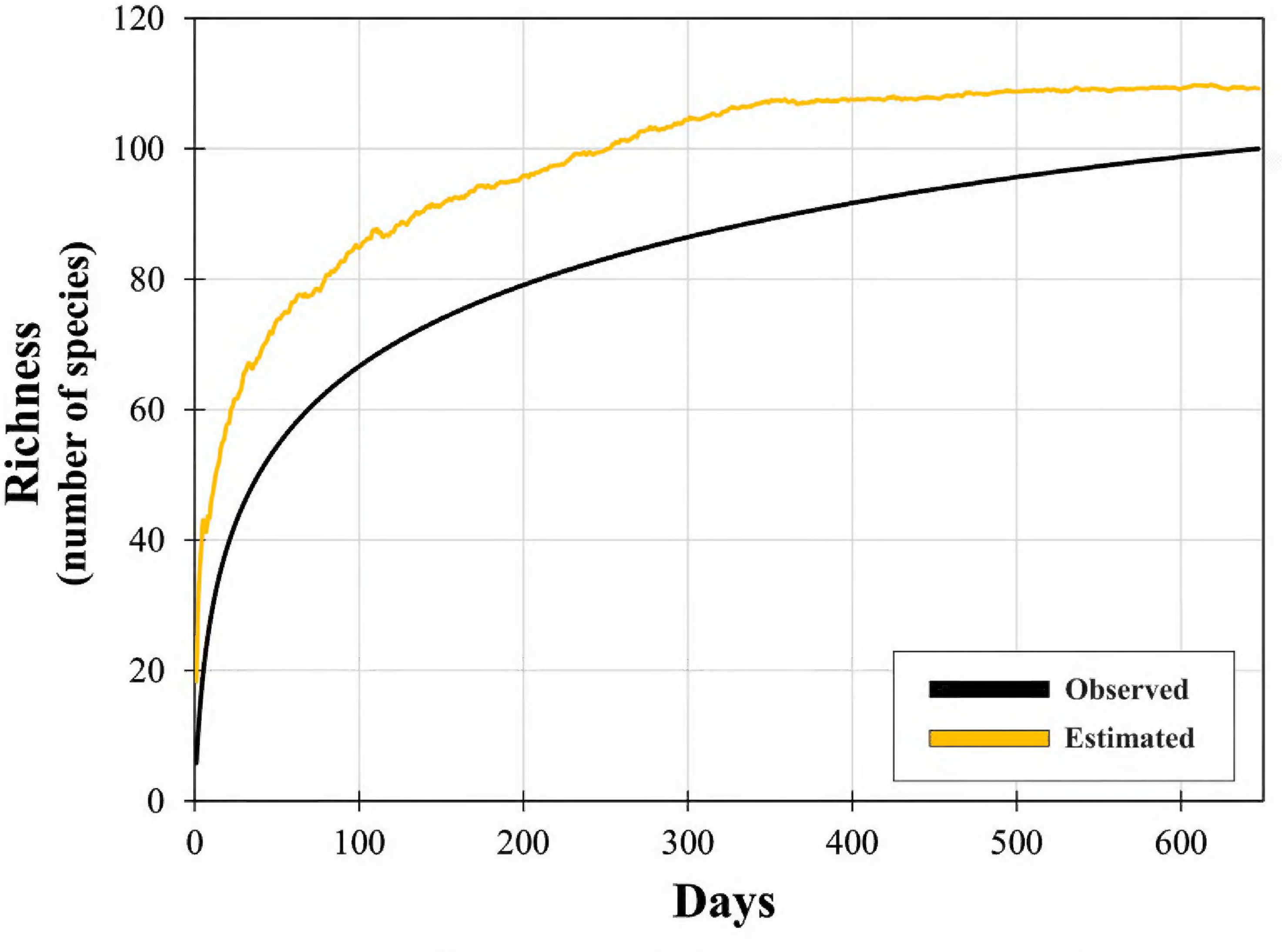

Figure 5. Curves of estimated (Chao 1) and observed species richness between 2014 and 2019 in premontane forests of the Magdalena River basin in eastern Caldas, Colombia.

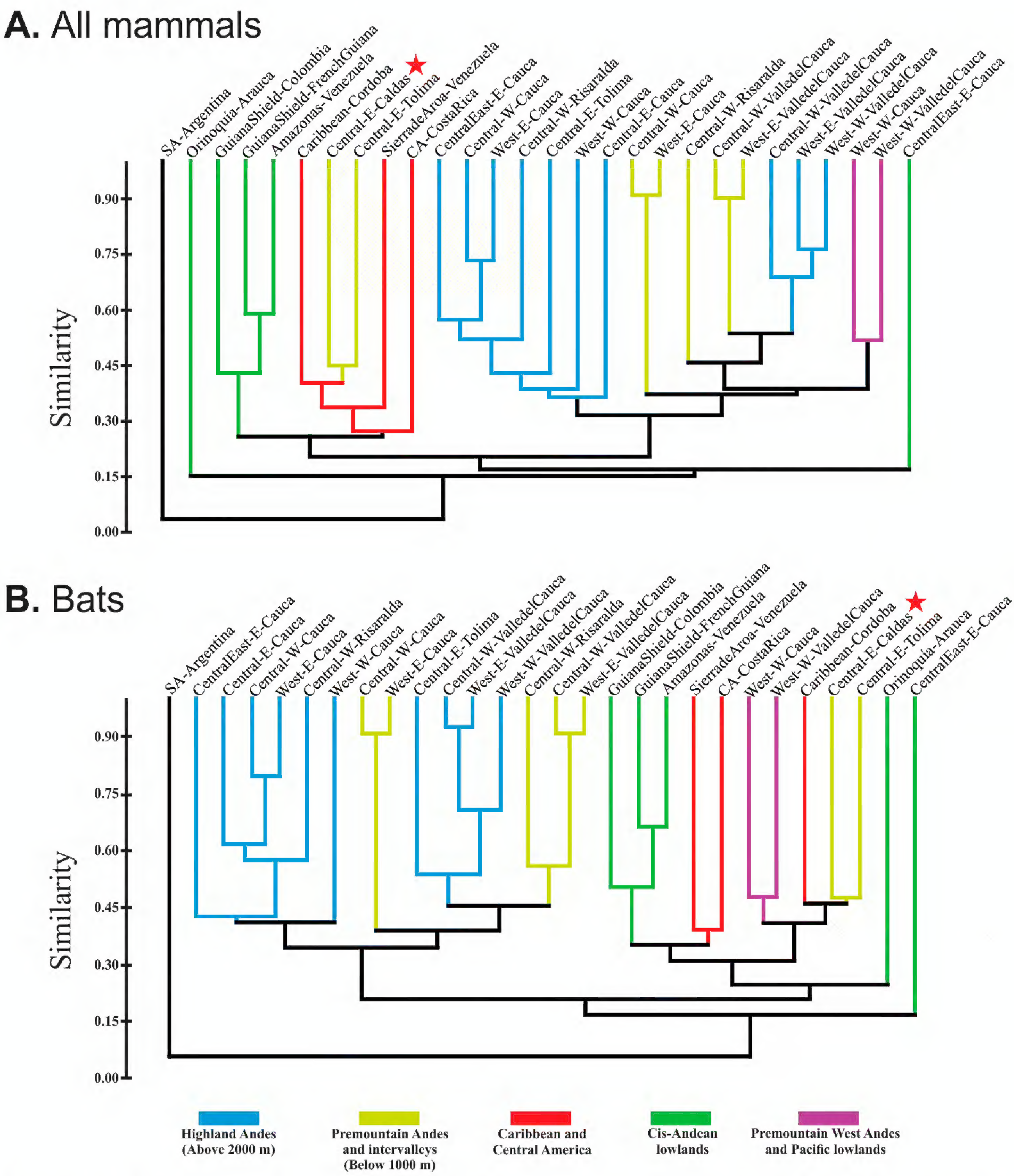

Figure 6. Dendograms showing the similarity in species composition (Jaccard Index) of mammals (**A**) and bats (**B**) amongst northern South America and Central America localities. Red star indicates the study area. Central, West and East refer to the three Andes Cordilleras in Colombia; W (west) and E (east) refers to the slopes of the Andes; SA (South America); CA (Caribbean); Central-East refers to the Colombian Massif.

Discussion

Premontane forests, located on the eastern slopes of the Central Andes below 1000 m in the Department of Caldas, sustain at least 101 species of mammals, mostly common species that are not listed as threatened. This number represented 19% of the mammalian richness in Colombia (528 species; Sociedad Colombiana

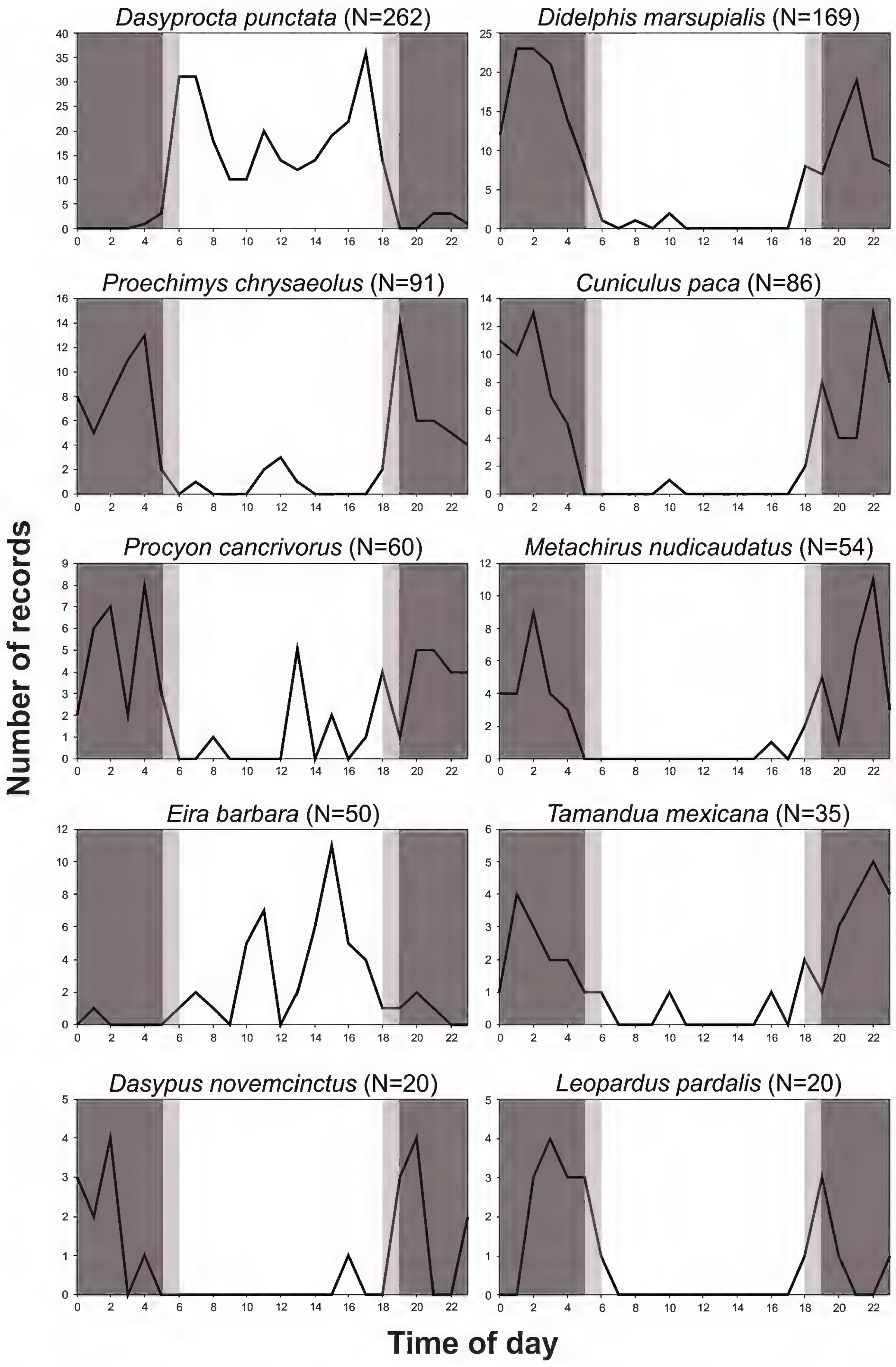

Figure 7. Activity patterns of some mammals between 2014 and 2019 in premontane forests of the Magdalena River basin in eastern Caldas, Colombia. Dark grey areas indicate hours of darkness, while light grey indicates twilight. Records represent the observations in trap-cameras during the six years of monitoring.

Table 1. Checklist of mammals in premontane forests of the Magdalena River basin in eastern Caldas, Colombia.

ORDER/FAMILY	Conservation status			Elevation	Records	Method	Municipality
	National	Global	Population trend	m			
DIDELPHIMORPHIA							
Didelphidae							
Caluromys lanatus		LC	Decreasing	494–850	10	Cam, Trap, Obs	Nor, Sam
Chironectes minimus		LC	Decreasing	501–816	16	Obs, Trap	Nor, Sam, Vic
Didelphis marsupialis		LC	Stable	303–880	245	Cam, MC, Trap, Obs	Nor, Sam, Vic
Marmosa phaea		LC	Stable	334–848	31	MC, Trap, Obs	Nor, Sam, Vic
Marmosa isthmica		Not evaluated	Unknown	324–867	84	Cam, MC, Trap	Nor, Sam, Vic
Marmosa robinsoni		LC	Stable	687–825	2	Trap	Sam
**Marmosops chucha*		Not evaluated	Unknown	450–808	17	MC, Trap	Nor, Sam, Vic
Metachirus myosuros		LC	Stable	461–860	98	Cam, MC, Trap, Obs	Nor, Sam, Vic
Monodelphis adusta		LC	Stable	542–795	3	Trap	Nor, Vic
Philander melanurus		LC	Stable	781	1	Cam	Vic
CINGULATA							
Dasypodidae							
Cabassous centralis		DD	Unknown	532–860	12	Cam, MC	Nor, Sam
Dasypus novemcinctus		LC	Stable	394–850	27	Cam, Obs	Nor, Sam, Vic
PILOSA							
Megalonychidae							
Choloepus hoffmanni		LC	Unknown	528–817	4	Obs	Nor, Sam
Myrmecophagidae							
Tamandua mexicana		LC	Unknown	487–860	35	Cam, Obs	Nor, Sam, Vic
CHIROPTERA							
Emballonuridae							
Centronycteris centralis		LC	Unknown	420	–	Castaño and Corrales (2007)	Nor
Cormura brevirostris		LC	Unknown	518–591	5	Obs, MisN	Nor, Sam
Peropteryx macrotis		LC	Stable	378	1	MisN	Vic
Rhynchonycteris naso		LC	Unknown	675	1	MisN	Sam
Saccopteryx bilineata		LC	Unknown	376–820	9	Obs, MisN	Nor, Sam, Vic
Saccopteryx leptura		LC	Unknown	468–686	6	MisN	Nor, Sam
Molossidae							
Cynomops greenhallii		LC	Unknown	675	4	MisN	Sam
Eumops hansae		LC	Unknown	675	2	MisN	Sam
Molossus bondae		LC	Stable	675	6	MisN	Sam
Noctilionidae							
Noctilio albiventris		LC	Stable	661	1	MisN	Sam
Noctilio leporinus		LC	Unknown	503–675	2	MisN	Sam, Vic
Phyllostomidae							
Anoura caudifer		LC	Unknown	379–822	7	MisN	Nor, Sam, Vic
Anoura geoffroyi		LC	Stable	819	3	MisN	Nor
Artibeus amplus		LC	Unknown	372–873	59	MisN	Nor, Sam, Vic
Artibeus bogotensis		LC	Stable	1000	5	MisN	Sam
Artibeus lituratus		LC	Stable	408–857	239	MisN	Nor, Sam, Vic
Artibeus phaeotis		LC	Unknown	353–873	207	MisN	Nor, Sam, Vic
Artibeus planirostris		LC	Stable	372–857	272	MisN	Nor, Sam, Vic
Artibeus ravus		LC	Stable	408–873	225	MisN	Nor, Sam, Vic
Carollia brevicauda		LC	Stable	353–887	1007	MisN	Nor, Sam, Vic
Carollia castanea		LC	Stable	353–887	973	MisN	Nor, Sam, Vic
Carollia perspicillata		LC	Stable	353–887	2693	MisN	Nor, Sam, Vic
Chiroderma salvini		LC	Stable	666	1	MisN	Sam
Chiroderma gorgasi		Not evaluated	Unknown	584–799	2	MisN	Nor, Sam
Choeroniscus aff. *minor*		LC	Unknown	794	1	MisN	Nor
Desmodus rotundus		LC	Stable	353–840	131	MisN	Nor, Sam, Vic
Glossophaga sp.		LC	Stable	408–812	17	MisN	Nor, Vic
Lampronycteris brachyotis		LC	Stable	372–666	12	MisN	Sam, Vic
Lichonycteris aff. *obscura*		LC	Unknown	654–778	13	MisN	Sam, Vic

ORDER/FAMILY	Conservation status			Elevation	Records	Method	Municipality
	National	Global	Population trend	m			
Lonchophylla robusta		LC	Unknown	478–819	8	MisN	Nor, Sam
Lonchorhina aurita		LC	Stable	372–694	100	MisN	Nor, Sam, Vic
Lophostoma brasiliense		LC	Stable	493–849	39	MC, MisN	Nor, Sam, Vic
Lophostoma silvicolum		LC	Unknown	511–668	2	MisN	Sam
Mesophylla macconnelli		LC	Unknown	493–845	66	MisN	Nor, Sam, Vic
Micronycteris hirsuta		LC	Unknown	830	1	MisN	Sam
Micronycteris megalotis		LC	Unknown	372	1	MisN	Vic
Micronycteris microtis		LC	Stable	518	2	MisN	Nor
Micronycteris minuta		LC	Unknown	373–763	2	MisN	Nor, Vic
Micronycteris schmidtorum		LC	Stable	468–853	10	MisN	Nor, Sam
Phylloderma stenops		LC	Stable	373–745	12	MisN	Nor, Sam, Vic
Phyllostomus discolor		LC	Stable	372–830	34	MisN	Nor, Sam, Vic
Phyllostomus hastatus		LC	Stable	372–830	19	MisN	Nor, Sam, Vic
Platyrrhinus helleri		LC	Stable	372–887	279	MisN	Nor, Sam, Vic
Sturnira ludovici		LC	Unknown	651–661	2	MisN	Sam
Sturnira sp.				372–887	771	MisN	Nor, Sam, Vic
Tonatia bakeri		Not evaluated	Unknown	468–644	18	MisN	Nor, Sam, Vic
Trinycteris nicefori		LC	Unknown	353–585	3	MisN	Sam, Vic
Uroderma convexum		Not evaluated	Unknown	376–873	37	MisN	Nor, Sam, Vic
Vampyressa thyone		LC	Unknown	478–853	126	MisN	Nor, Sam, Vic
Vampyrum spectrum		NT	Decreasing	505	2	MisN	Nor
Thyropteridae							
Thyroptera tricolor		LC	Unknown	502–742	10	MC, MisN	Sam, Vic
Vespertilionidae							
Eptesicus brasiliensis		LC	Unknown	814–826	5	MisN	Nor, Sam
Eptesicus chiriquinus		LC	Unknown	805–819	2	MisN	Nor, Sam
Myotis riparius		LC	Stable	372–887	99	MisN	Nor, Sam, Vic
Rhogeessa io		LC	Unknown	567–846	2	MisN	Nor, Sam
CARNIVORA							
Canidae							
Cerdocyon thous		LC	Stable	461–871	27	Cam, Obs	Nor, Sam, Vic
Felidae							
Leopardus pardalis		LC	Decreasing	475–864	22	Cam, Obs	Nor, Sam
Mustelidae							
Eira barbara		LC	Decreasing	389–868	61	Cam, Obs	Nor, Sam, Vic
Galictis vittata		LC	Stable	748–814	4	Cam	Nor, Sam
Lontra longicaudis	Vu	NT	Decreasing	475–585	4	Obs, Tra	Nor, Sam
Mustela frenata		LC	Stable	–	–	Castaño and Corrales (2010)	Nor
Procyonidae							
Nasua nasua		LC	Decreasing	666	1	Cam	Sam
Potos flavus		LC	Decreasing	295–843	19	Obs	Nor, Sam, Vic
Procyon cancrivorus		LC	Decreasing	486–887	61	Cam, Obs	Nor, Sam, Vic
ARTIODACTYLA							
Tayassuidae							
Pecari tajacu		LC	Stable	499–692	42	Cam	Sam, Vic
Primates							
Atelidae							
Alouatta seniculus		Not evaluated	Unknown	460	1	Obs	Vic
Cebidae							
Aotus griseimembra	Vu	Vu	Decreasing	416–853	132	Obs	Nor, Sam, Vic
Saguinus leucopus	Vu	EN	Decreasing	372–887	424	Cam, Obs	Nor, Sam, Vic
**Cebus versicolor*		EN	Decreasing	1000	1	Obs	Sam
RODENTIA							
Cricetidae							
Handleyomys alfaroi		LC	Stable	320–828	20	Trap	Nor, Sam
Ichthyomys hydrobates		NT	Decreasing	797–800	2	Obs, Trap	Nor, Sam
Melanomys caliginosus		LC	Stable	333–804	65	Trap	Nor, Sam, Vic
Neacomys tenuipes		LC	Stable	491–891	64	Cam, MC, Trap, Obs	Nor, Sam, Vic

ORDER/FAMILY	Conservation status			Elevation	Records	Method	Municipality
	National	Global	Population trend	m			
**Nectomys grandis*		DD	Unknown	658–826	17	Trap	Nor, Sam
**Rhipidomys caucensis*		DD	Unknown	509–781	10	Trap	Nor, Sam
Rhipidomys latimanus				334–801	3	Trap	Nor, Vic
Sigmodon hirsutus		LC	Increasing	475–808	3	Trap	Nor, Vic
Transandinomys talamancae		LC	Stable	790–825	8	Trap	Sam
Tylomys mirae		LC	Unknown	314–891	124	Cam, MC, Trap, Obs	Nor, Sam, Vic
**Zygodontomys* aff. *brunneus*		LC	Stable	475–521	15	Trap	Nor
Cuniculidae							
Cuniculus paca		LC	Stable	488–838	92	Cam, Obs	Nor, Sam, Vic
Dasyproctidae							
Dasyprocta punctata		LC	Stable	390–860	268	Cam, Obs	Nor, Sam, Vic
Dinomyidae							
Dinomys branickii	Vu	LC	Unknown	849	1	Obs	Vic
Echimyidae							
**Proechimys chrysaeolus*		DD	Unknown	303–829	161	Cam, Obs, Trap	Nor, Sam, Vic
Erethizontidae							
Coendou quichua		DD	Decreasing	510	1	Obs	Nor
Heteromyidae							
Heteromys australis		LC	Stable	730–840	5	Trap	Sam
Sciuridae							
Syntheosciurus granatensis		LC	Stable	460–887	36	Cam, Obs	Nor, Sam, Vic
Leptosciurus pucheranii		DD	Unknown	468–888	13	Cam, MC, Obs	Nor, Sam
LAGOMORPHA							
Leporidae							
Sylvilagus sp.		–	–	497	1	Cam	Vic

National (resolución 1912 de 2017) and global (Red List of IUCN) conservation status: **DD** (data deficient), **LC** (least concern), **NT** (near threatened), **VU** (vulnerable), **EN** (endangered). Methods: **Cam** (camera trap), **MC** (manual capture), **MisN** (mist net), **Obs** (direct observation), **Trap** (Sherman and Tomahawk traps). Municipalities: **Nor** (Norcasia), **Sam** (Samaná), **Vic** (Victoria).

de Mastozoología et al. 2020) and it is expected to increase with additional sampling efforts. Bats as the richest order and rodents as the second follow the same pattern found at the national scale (Solari et al. 2013).

We expected to find, according to the estimator Chao 1, at least nine species more if the sampling effort were increased. Checklists of mammals in localities in the Magdalena River basin report species that were not found in the study area, but their presence is highly probable, especially bats such as *Myotis caucensis*, *M. albescens*, *Pteronotus parnellii*, *Trachops cirrhosus*, some molossid species and nectarivorous bats, such as *Hsunycteris thomasi* and *Lionycteris spurrelli* (García-Herera et al. 2019; Solari et al. 2020). Some carnivorous mammals, such as *Herpailurus yagouaroundi* or *Bassaricyon neblina*, are also expected (Sánchez-Giraldo and Daza 2017; Gerstner et al. 2018). Besides increasing the sampling effort, it is important to focus it on habitats where rare species concentrate their activities. This was the case of the bat *Eumops hansae*, which was captured over the Manso River in a net set across the river, a method that was rarely used in this or other studies; the specimen captured by this method was the first reported for the country (Torres and Rojas 2020).

The mammalian fauna found in the study area is composed mostly of common species with wide geographic ranges; however, the presence of seven Colombian endemic small mammals with restricted geographic ranges associated with premontane and cloud forests in the Magdalena River basin emphasises the conservation

value of premontane forests in the east of the Department of Caldas; indeed, this area had already been identified as a regional centre of mammalian endemisms (Castaño 2012). Since non-volant small mammals have low dispersal ability, local deforestation associated with agricultural activities can cause local population extinctions of these endemic species and restrict them to isolated forested areas (Castro and Fernandez 2004, Paise et al. 2020). This is especially true for the marsupial *Marmosops chucha*, the rodent *Rhipidomys caucensis* and the primate *Saguinus leucopus* that carry out their activities above the ground in the lower, middle and upper forest strata (pers. obs., Poveda and Sánchez-Palomino 2004). To ensure the survival in the long term for these endemic species, it is imperative to increase the connectivity of forest fragments and maintain the already existing corridors such as riparian forests and living fences (Zimbres et al. 2017).

Most species in the study area are not listed in lower threatened categories (LC or NT); however, 10 species showed a globally-decreasing population trend. This pattern is part of a world phenomenon known as defaunation, which means the progressive loss of animal populations caused mainly by habitat loss (Dirzo et al. 2014). Interestingly, eight of the eleven species with decreasing populations, according to the Red List, feed on other animals (i.e. animalivorous), despite belonging to different taxonomic groups, such as bats (*Vampyrum spectrum*), carnivores (*Leopardus pardalis* or *Lontra longicaudis*), marsupials (*Chironectes minimus*) and rodents (*Ichthyomys hydrobates*). Animalivory is a functional trait of species that has been associated with increased vulnerability to habitat loss and fragmentation because of their lower population densities and slow life histories (Cardillo et al. 2004; Minin et al. 2016).

Since ambient temperature is an important determinant of the distribution of many animals (Bozinovic et al. 2011) and the inter-Andean valley, through which the Magdalena River flows, opens in the north, the faunistic similarity between the study area and the warm Caribbean Region in Colombia, Costa Rica and Venezuela was not surprising. This inter-Andean valley could be defined as a "warm corridor" for mammalian species adapted to these warm environmental conditions. The warm lowlands similarity was also supported by the fact that mammalian fauna in the Central Cordillera below 1000 m (both the study area and Tolima) and the Caribbean localities are more related to the warm lowlands of the Amazon and Guiana Shield, than they are to closer regions like West and Central Cordilleras above 2000 m, which have lower temperatures. Our analysis restricted to bats also points to this relationship and adds to the group of "lowland fauna", the bat fauna of the Pacific Region below 1000 metres.

Similar relationships between lowland areas have also been described for birds (Kattan et al. 2004; Cadena et al. 2016). For these flying vertebrates, it has been hypothesised that relationships amongst lowland areas in northern South America were mediated by dispersal events (Cadena et al. 2016). One hypothesis is that this dispersion occurred throughout the north in the Caribbean lowlands (Haffer 1967a, b). Another hypothesis proposes that this occurred through passes in the Andes, such

as the Táchira depression in northern East Cordillera or Andalucía pass and Suaza-Pescado valleys at the south of this same Cordillera (Cadena et al. 2016). Possible examples of this historical dispersion in mammals may be the bats *Artibeus planirostris* and *Sphaeronycteris toxophyllum* which are distributed in the lowlands east of the Andes, but also extend their distribution into the Magdalena River basin and Caribbean Region (Solari et al. 2013; García-Herrera et al. 2018). At least in the case of *A. planirostris*, molecular evidence suggests dispersion from the Guiana Shield and Venezuela into the Lesser Antilles and northern South America (Larsen et al. 2007).

Most analysed mammal species were active during the night, beginning at dusk and finishing at sunrise. This is the typical mammalian pattern; and, as it is currently understood, this was the ancestral behaviour of the placental mammalian ancestor (Gerkema et al. 2013); thus, activity during the day, as shown by some species, may be considered a derived behavioural trait. In general, the activity patterns of many Neotropical mammals of medium and large size are well-known (e.g. Blake et al. 2012; Ramírez-Mejía and Sánchez 2016; Huck et al. 2017); however, the small mammals activity patterns are under-studied (Ferreira and Vieira 2016). Thus, the data, shown in this study on the activity patterns of the endemic spiny rat *Proechimys chrysaeolus*, are an important contribution to this topic. The activity pattern of *P. chrysaeolus* was similar to the patterns found in other species of *Proechimys* in the Brazilian Amazon (Pratas-Santiago et al. 2016).

Conclusion

Premontane forests of the Magdalena River basin in eastern Caldas harbour a rich mammalian fauna, consisting mostly of common species of lowland origins. However, these forests are of high conservation value because they host at least seven endemic species and five Endangered or Vulnerable species. To secure the long-term persistence of these species, we recommend maintaining the current corridors, such as riparian forests and living fences and increasing the forested area.

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Supplementary material 1

Presence/absence matrix of 548 species of mammals from 28 regions in Central and South America

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Data type: Presence/absence matrix

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